EXHIBIT P

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DRAFT WINTER-RUN JUVENILE PRODUCTION ESTIMATE (JPE) FOR BROOD YEAR 2021

Dear Mr. Yip and Dr. Jacobs:

In 2013, the Interagency Ecological Program's Winter-Run Chinook Salmon Project Work Team (Winter-Run PWT) recommended that the National Marine Fisheries Service (NMFS) Juvenile Production Estimate (JPE) be revisited annually and updated as needed with any new or improved information. The annual JPE is used to calculate loss thresholds for Long-Term Operation of the Central Valley Project and the State Water Project, as described in the NMFS Biological Opinion, No. WRCO-2016-00069 (2019 NMFS BiOp) and required by CDFW Incidental Take Permit No. 2081-2019-066-00 (2020 ITP). A subgroup of the Winter-Run PWT met four times in December 2021 to review and update the factors used to calculate the brood year (BY) 2021 JPE, and to develop a recommended draft winter-run JPE for BY 2021, with the final recommendation pending approval at the Winter-Run PWT's January meeting. The Winter-Run PWT's recommendations resulting from this review are described below.

<u>JPE Recommendations</u>

The Winter-Run PWT identified several factors in calculating the JPE that we advise be continued or updated for BY 2021. We considered one method for forecasting natural-origin JPE—The "Method 2" approach used for the BY 2019 and BY 2020 JPEs and described in O'Farrell et al. (2018). The data inputs for the calculations include estimates of the following parameters for calculating JPE for natural-origin BY 2021 winter-run Chinook ($JPE_{Natural}$) (Figure 1):

1) Number of winter-run fry equivalents passing Red Bluff Diversion Dam (RBDD)(JPI_{Fry})
2) Survival rate of natural-origin fry to smolts ($Survival_{Fry\text{-}to\text{-}Smolt}$)
3) Survival rate of smolts from RBDD to Delta entry (defined as Sacramento at the I-80/I-50 Bridge) ($Survival_{Smolt}$)

<u>Hatchery Release JPE Recommendations</u>

Additionally, we used the number of winter-run hatchery smolts expected to be released from Livingston Stone National Fish Hatchery (LSNFH) in February 2022 ($N_{Hatchery}$) and their predicted survival rate ($Survival_{HatcherySmolt}$) to estimate a JPE of hatchery-origin winter-run juveniles in the Delta ($JPE_{Hatchery}$) (Figure 1). We present the data inputs used in the calculations in Table 1 and describe each in the sections below.

For the second year in a row, we also include estimates of hatchery-origin winter-run smolts released in Battle Creek as part of the “Jumpstart” reintroduction ($N_{BCJumpstart}$), their survival ($Survival_{BCJumpstart}$), and a forecast of the number entering the Delta ($JPE_{BCJumpstart}$). Although there was natural spawning in Battle Creek in 2021, we do not differentiate naturally produced juveniles from Battle Creek from Sacramento River juveniles, and both are included in the JPI_{Fry}.

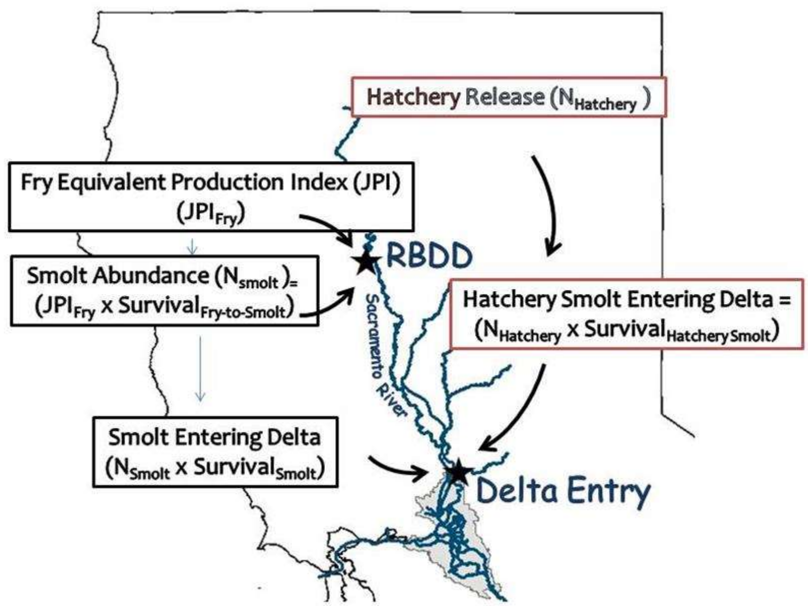

Figure 1. Location and formulas recommended for use in the JPE for the natural-origin (black boxes) and hatchery-origin (red boxes) components of the winter-run population estimated for BY 2021. Separate hatchery JPEs are estimated for hatchery releases from Livingston Stone Fish Hatchery into the Sacramento River ($N_{Hatchery}$) and for the Battle Creek Jumpstart hatchery releases into Battle Creek (not shown).

Winter-Run JPE Methods for 2021-2022

The Winter-Run PWT focused on a single method for forecasting the JPE for BY 2021, as was done for BY 2020. This method was recommended in O’Farrell et al. (2018) and was the chosen method for BY 2019. It is the opinion of the Winter-Run PWT that this method represents the best available science for estimating an annual JPE given currently available data.

Juvenile Production Index - For the BY 2021 JPE, the Winter-Run PWT continues to recommend using the Juvenile Production Index (JPI_{Fry} or JPI), which is based on an estimate of fry equivalents at RBDD. The JPI has been used in the calculation since 2014 and better represents the response of fish to annual environmental conditions during spawning, egg incubation, and outmigration, as compared to the long-term average egg-to-fry survival rate used in the JPE prior to 2014. This is of particular importance this year, as the JPI approach at least

partially accounts for lower than average egg-to-fry survival in naturally spawned winter-run Chinook Salmon expected for BY 2021 due to thiamine deficiency in spawners and temperature-related mortality during egg incubation.

There are two updates worth noting about the winter Chinook JPI estimate this year. The first update is to the trap efficiency model employed in 2021. In response to changes in river channel geometry and juvenile trap configurations, USFWS updated the least-squares regression model used to predict daily trap efficiency, which expands RST catch to estimate the JPI. The new model uses data from efficiency trials conducted between 2018 and 2021 using natural-origin fall- and winter-run Chinook Salmon (n=32 trials; B. Poytress, USFWS, pers. comm.) and incorporates 13 trials conducted under the new trap configuration (four 5-ft traps and one 8-ft trap). Due to low catches of naturally produced winter-run Chinook Salmon in 2021, a single efficiency trial was conducted in Fall 2021. That trial has not yet been incorporated into the 32-trial model, but it fell within the 90 percent prediction interval of the current model, which supports use of the currently active model for winter-run Chinook Salmon in 2021.

The second difference in the 2021 JPI estimate was the need to interpolate passage data for 2 unsampled days during an unprecedented storm and runoff event in October when juvenile traps at RBDD could not safely operate. Juvenile capture during that time was interpolated using the weekly mean, which is the standard procedure (as described in Voss and Poytress 2020). Because the data gap occurred during the season's largest increase in flow, which oftentimes triggers increased juvenile migration (Poytress et al. 2014), the JPI may underestimate juvenile passage during that period.

Fry-to-Smolt Survival - The Winter-Run PWT recommends the continued inclusion of a fry-to-smolt survival factor ($\text{Survival}_{\text{Fry-to-Smolt}}$). This is necessary because the available survival estimates between RBDD and the Delta are based on releases of acoustically telemetered smolts, which have a higher survival rate than fry. Without this factor, the survival rate from fry to smolts is assumed to be 1.00, which is unrealistic. The same factor is used to adjust juvenile passage at RBDD to fry equivalents, based on the peak of fry catch at RBDD (generally in October) and the smolt life-stage at RBDD for naturally produced winter-run Chinook.

The Winter-Run PWT recommends the fry-to-smolt survival rate forecasting method developed by O'Farrell et al. (2018), which uses recent winter-run Chinook Salmon survival data and is updated with new survival data annually. Incorporating updated survival rate estimates, this method results in a winter-run Chinook Salmon fry-to-smolt survival rate of 0.4429 for BY 2021. The team recommends using this forecasting method to estimate fry-to-smolt survival in calculations of JPE and updating the fry equivalent multiplier to 2.258 (the factor 2.258 is the inverse of 0.4429). It is the opinion of the Winter-Run PWT that these updated values, which are based on peer-reviewed methodologies and more recent winter-run Chinook data, improve the JPE forecast compared to values used prior to 2019.

Fry Production - The JPI seasonal estimate of fry equivalents using the 0.4429 fry-to-smolt survival rate was 761,839 as of December 16, 2021 (week 50; B. Poytress, USFWS, personal communication). The value through December 16 accounts for approximately 95.66 percent of annual winter-run passage at RBDD based on data collected from 2002 to 2020. Including an interpolation of the remaining 4.34 percent to account for the remainder of BY 2021, the total BY 2021 estimate is 796,403 fry equivalents (Table 1). This value accounts for in-season winter-run genetic corrections, which have a minimal effect on the estimate. With this estimate of fry production at RBDD, the estimated egg-to-fry survival is calculated to be 0.0256 (Table 1).

Table 1 – Reported population estimates and survival factors for brood year 2021
(Factors used in the JPE calculations and the resulting JPEs are shown in bold.)

Component	Natural	Hatchery
Total Sacramento River escapement[1]	9,956	
Adult female estimate (AFE)[2]	6,199	
AFE minus pre-spawn mortality[3] (5.5%) ($N_{Spawners}$)	5,860	
Average fecundity[4] (AF)	5,312	
Total eggs	31,128,320	
Estimated egg-to-fry survival rate based on JPI at RBDD/Total eggs[5]	0.0256	
Fry equivalents of juvenile production at RBDD (JPI or JPI_{Fry})[6]	**796,403**	
Fry-to-smolt survival ($Survival_{Fry\text{-}to\text{-}Smolt}$)[7]	**0.4429**	
Number of smolts at RBDD	352,727	
Estimated smolt survival term: RBDD to Delta ($Survival_{Smolt}$)[8]	**0.3537**	
Total natural production entering the Delta (JPE)	**124,760**	
JPE 95 percent confidence interval	58,840 – 190,679	
LSNFH Hatchery release ($N_{Hatchery}$)[9]		**537,771**
Survival rate from release to Sacramento ($Survival_{HatcherySmolt}$)[10]		**0.2818**
Total LSNFH production entering the Delta		**151,544**
Battle Creek Hatchery release ($N_{BCJumpstart}$)[11]		**180,000**
Survival rate from release to Sacramento ($Survival_{BCJumpstart}$)[12]		**0.0519**
Total Jumpstart production entering the Delta		**9,342**

1/ Total Sacramento River in-river escapement from CDFW Cormack-Jolly Seber (CJS) model includes natural- and hatchery-origin winter-run Chinook Salmon, but not hatchery fish retained for brood stock at LSNFH.

2/ The number of adult females is derived from carcass surveys on the Sacramento River. Naturally spawning winter-run Chinook Salmon in Battle Creek are not included.

3/ Pre-spawn mortality was estimated from carcass surveys of females (Doug Killam, CDFW, pers. comm.).

4/ Preliminary (subject to change) average number of eggs per female from 118 female fish spawned at LSNFH (Kaitlin Gooding, USFWS pers. comm.).

5/ Back calculated estimated survival between eggs laid in-river and fry production estimates at RBDD based on numbers of fry equivalents (JPI) using the 0.4429 fry-to-smolt survival rate estimate based on method described in O'Farrell et al. (2018).

6/ Preliminary number of fry equivalents estimated on December 16, 2021 plus 4.34% interpolation to account for remainder of estimated passage for the 2021 brood year at RBDD; using 0.4429 fry-to-smolt survival rate estimate (Bill Poytress, USFWS, pers. comm.). This estimate includes and does not differentiate between the number of fry equivalents outmigrating from Battle Creek and the Sacramento River.

7/ Estimate of fry-to-smolt survival rate based on O'Farrell et al. (2018), updated using data from BY 1998-2016.

8/ Variance-weighted mean survival rate of acoustically tagged hatchery winter-run Chinook Salmon from 2013 to 2021 between RBDD and I-80/Tower Bridge in Sacramento (based on O'Farrell et al. 2018). Survival is estimated from the Salt Creek receiver site, located 3 miles downstream of RBDD, to estimate survival from RBDD for natural-origin smolts.

9/ Estimated LSNFH production release as of December 15, 2021 (100% tagged and adipose clipped).

10/ Variance-weighted mean survival rate of acoustically tagged hatchery winter-run Chinook Salmon from 2013 to 2021 between release location and I-80/Tower Bridge in Sacramento (based on O'Farrell et al. 2018).

11/ Estimated Battle Creek Jumpstart release as of December 15, 2021 (100% tagged and marked).

12/ Variance-weighted mean survival rate of acoustically tagged hatchery winter-run Chinook Salmon from 2019 to 2021 between release location in North Fork Battle Creek and I-80/Tower Bridge in Sacramento (based on O'Farrell et al. 2018). The survival rate of 64 fish on released on May 18, 2020 was not included in this calculation because fish size and environmental conditions did not represent expected conditions during the BY 2021 winter release.

Natural-origin Smolt Survival - To estimate survival of natural origin winter-run smolts from RBDD (i.e., Salt Creek) to the Delta (i.e., Sacramento at the I-80/I-50 Bridge)($Survival_{Smolt}$), the Winter-Run PWT recommends using the variance-weighted mean of survival estimates from acoustically tagged LSNFH smolts released in 2013–2021, as described in O'Farrell et al. (2018). This calculation is updated each year to incorporate survival and variance estimates from the previous year and uses the Cormack-Jolly-Seber model, which accounts for variation in detection probabilities. The estimated annual survival rate using this method is 0.3537. Note that the release-specific survivals for all years were recalculated for this year's estimate based on an updated filtering algorithm (Danner and Ammann, 2021).

Hatchery Smolt Survival – To estimate survival of hatchery-produced winter-run released in the Sacramento River near Redding ($Survival_{HatcherySmolt}$), we recommend using the variance-weighted mean of 2013–2021 survival rates from the LSNFH release point to the Delta. This survival rate is 0.2818. For hatchery-produced winter-run released in North Fork Battle Creek ($Survival_{BCJumpstart}$), we recommend using the variance-weighted mean of 2019–2021 survival rates from the Battle Creek release point to the Delta (excluding the May 2020 release because fish size and environmental conditions did not represent expected conditions during the BY 2021 winter release). This survival rate is 0.0519. Because both release points of hatchery fish are upstream of RBDD, the overall survival to the Delta is lower compared to the survival applied to natural-origin smolts. As for natural-origin smolt survival, these estimates of hatchery smolt survival use the Cormack-Jolly-Seber model to account for variation in detection probabilities and are updated annually to incorporate survival and variance estimates from the previous year.

Discussion on low estimated egg-to-fry survival for BY 2021

The approach described above allows us to back-calculate egg-to fry survival based on estimates of the number of successful female spawners ($N_{Spawners}$), average female fecundity (AF), and JPI, as described under "Fry Production" and in Equation 1. This calculation can be a useful metric to compare to average or expected survival in order to identify mortality occurring during egg incubation and fry emergence. Using this equation, estimated BY 2021 egg-to-fry survival for winter-run Chinook Salmon is 0.0256. The two primary factors contributing to low egg-to-fry survival in BY 2021 are thought to be temperature dependent mortality and thiamine deficiency complex.

Equation 1:

$$Survival_{Egg-to-Fry} = \frac{JPI_{Fry}}{N_{Spawners} \times AF}$$

Winter-run Chinook Salmon in 2021 spawned during one of the warmest and driest years on record, and Sacramento River water temperatures during the majority of the incubation period exceeded limits for safe egg incubation. Using the Martin et al. (2017) model, NMFS estimated mean annual temperature dependent mortality of winter-run Chinook Salmon eggs at 75 percent (25–75% confidence interval of 64–81%), based on measured water temperatures and mapped winter-run Chinook Salmon spawning locations in the Sacramento River in 2021 (SWFSC, 2021).

Additional early life stage mortality was likely due to thiamine deficiency complex syndrome, thought to be the result of shifts in marine forage fish species off the coast of California. Thiamine concentrations in egg samples from 30 females spawned at LSNFH in 2021 showed 83 percent of females with thiamine low enough where some fry mortality would be expected (T. Lipscomb,

USFWS, pers. comm.). Any thiamine deficiency impacts manifested in egg viability or early fry stages will lead to a reduced JPI compared to what would have been observed absent thiamine deficiency impacts. USFWS had only one observation of abnormal fry behavior at the RBDD rotary screw traps (B. Poytress, USFWS, pers. comm.), suggesting that mortality caused by thiamine deficiency occurred primarily upstream of RBDD, though there may be latent impacts to young-of-year winter-run Chinook Salmon downstream of RBDD that cannot be estimated based on information available this year. The assumption that most mortality would occur prior to outmigration is consistent with observations at Central Valley hatcheries, where mortality and behavioral abnormalities associated with thiamine deficiency in hatchery-origin juveniles were documented soon after hatch. Survival studies of untreated fish would be necessary to understand lower survival due to latent effects of thiamine deficiency.

Uncertainty exists within all three of the variables used to calculate an estimate of egg-to-fry survival. Female spawners and fecundity estimates are not used in the JPE calculation, and their uncertainty is not quantified during JPE development. Uncertainty in the JPI is quantified, and it is a factor considered in the JPE calculation and in the back-calculation of egg-to-fry survival. For 2021, the nonoperation of the juvenile traps at RBDD for two days during a substantial storm event in October, and potential underestimate of passage during that event for the JPI, may contribute to the relatively low estimate of egg-to-fry survival. Standard methods used to interpolate juvenile fish passage data for unsampled days (see Voss and Poytress 2020) during the October flow event likely resulted in a slight negative bias to the juvenile passage estimates for those days. However, the impact of those two interpolated days on the total JPI calculated for the entire BY 2021 outmigration season is likely captured within the uncertainty (confidence intervals) of the 2021 JPI. The current range of uncertainty around the preliminary point estimate JPI would result in an egg-to-fry survival estimate of between 0.0165 and 0.0347.

It is unknown how much each of these factors may be contributing to the low estimated egg-to-fry survival for BY 2021, but there are ongoing efforts to better understand the contribution of each and any interactions between them. It is important to note that because the method used to calculate the JPE uses the JPI approach, any uncertainty due to the cause of mortality does not affect the JPE. Uncertainty in the JPE as a result of uncertainty in the JPI is captured in the 95 percent confidence intervals shown in Table 1.

Winter-Run PWT Recommended Method for BY 2021

The Winter-Run PWT recommends the previously described inputs and the following equations be used for estimating the BY 2021 natural-origin (Equation 2) and hatchery-origin (Equations 3 and 4) JPE:

Equation 2:

$$JPE_{Natural} = JPI_{Fry} \times Surviva_{Fry-to-Smolt} \times Survival_{Smolt}$$

$$= 796{,}403 \times 0.4429 \times 0.3537 = 124{,}760$$

Equation 3:

$$JPE_{Hatchery} = N_{Hatchery} \times Survival_{HatcherySmolt}$$

$$= 537{,}771 \times 0.2818 = 151{,}544$$

Equation 4:

$$JPE_{BCJumpstart} = N_{BCJumpstart} \times Survival_{BCJumpstartSmolt}$$

$$= 180{,}000 \times 0.0519 = 9{,}342$$

It is the opinion of the Winter-Run PWT that this method represents the best available science for estimating a JPE given currently available data. It accounts for detection probabilities and quantifies uncertainty associated with estimates of JPI_{Fry} and smolt survival rates, which are used to develop the 95 percent confidence intervals for the JPE forecast. Because it does not capture process error, or the variation in true survival rates from year to year, these confidence intervals likely underestimate the uncertainty in the JPE forecast. We acknowledge that this method still has considerable uncertainty, and that confidence intervals may not have utility to water mangers under the current management setting. However, there is uncertainty with any forecast method for a JPE, and we believe there is value in quantifying and reporting that uncertainty.

It is the opinion of the Winter-Run PWT that this recommendation is the best information currently available from which to derive a draft JPE and the best method for arriving at estimates. We anticipate the Winter-Run PWT will issue a final recommendation by January 14, 2022. We conclude that this analysis and these technical recommendations from the Winter-Run PWT will establish the most accurate forecast of JPE for use in the 2022 water year at the Central Valley Project and State Water Project export facilities.

Sincerely,

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